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## DRAG MEASUREMENTS OF A PROTRUDING .50-CALIBER MACHINE GUN WITH BARREL JACKET REMOVED

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MEMORANDUM REPORT

for

Bureau of Aeronautics, Navy Department

# DRAG MEASUREMENTS OF A PROTRUDING .50-CALIBER MACHINE GUN WITH BARREL JACKET REMOVED

By Arvo A. Luoma

## SUMMARY

Tests were made in the NACA 8-foot high-speed tunnel to determine the drag reduction possible by eliminating the barrel jacket of a protruding .50-caliber aircraft gun.

It was found that the drag of a standard aircraft gun protruding into the air stream at right angles to the flow can be reduced by 23 percent by discarding the barrel jacket. At 350 miles per hour and sea-level conditions this amounts to a drop in drag from 83 to 64 pounds and a decrease in horsepower absorbed by drag from 78 to 60 horsepower.

A rough surface finish on the barrel was found to have no adverse effects on the drag of the barrel, the drag being actually less at high Mach numbers. The significance of this is that, as far as aerodynamic considerations are involved, a barrel finish produced by a rough machining operation is no worse - but probably somewhat better - than one produced by a fine machining operation.

## INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department,

tests were made in the NACA 8-foot high-speed tunnel to determine the drag reduction possible by eliminating the barrel jacket of a protruding .50-caliber aircraft gun. According to the Navy Department, firing tests have shown that the dispersion patterns of a .50-caliber aircraft gun which had been modified by removing the jacket and substituting a short bearing forward of the trunnion are equally as good as those of the standard gun.

In reference 1 the air drag of a standard .50-caliber aircraft gun was determined, as well as the basic data necessary to permit the calculation of the power to drive such protruding guns when used in power-operated turrets. In the present tests similar data were obtained for a .50-caliber aircraft gun with the barrel jacket removed. The effect on drag of roughness on the barrel surface (e.g., roughness due to coarse machining operations) was also determined.

## APPARATUS AND METHODS

These tests were made in the NACA 8-foot high-speed tunnel. This is a single-return, circular-section, closed-throat tunnel and has an airspeed continuously controllable from approximately 75 to more than 500 miles per hour.

A .50-caliber aircraft gun, which the Aircraft Armament Unit, Naval Air Station, Norfolk, Va., modified by removing the barrel jacket, was used in the tests. However, the short bearing, which was substituted for the barrel jacket and which

was located forward of the trunnion, was not included on the wind-tunnel model. With the gun pivoted as shown in figure 1 and when perpendicular to the air flow, the bearing would have projected approximately 1 inch into the stream boundary layer - which is about 5 inches thick - on the tunnel wall, and the increment of drag due to the protruding part of the bearing in the low-velocity air of the boundary layer would be negligible. Moreover, when the gun barrel is swung through an angle range, the bearing moves completely out of the air stream. It was decided, therefore, not to represent the bearing on the model. The model setup and the method of testing were the same as in reference 1. The same angle range was covered but higher speeds were included.

## RESULTS AND DISCUSSION

The following symbols are used (see fig. 1):

$\alpha$ angle made by the barrel of the machine gun with the perpendicular to the air flow; the angle of the gun is positive when the gun muzzle points into the air stream

$L$ length of gun protruding into air stream, measured along gun axis

$D_a$ average outside diameter of length of barrel $L$ protruding into air stream

$A$ axial cross-section area of barrel in air stream; this area is equal to $L \times D_a$

$C_D$ drag coefficient based on area A

$C_c$ cross-wind force coefficient based on area A; (see fig. 1 for definition of positive direction)

$l$ projection of length L on plane perpendicular to air flow ($l = L \cos \alpha$)

d distance from top of tunnel wall to center of pressure of resultant air force on gun axis, measured parallel to $l$

$C_p$ center-of-pressure coefficient ($d/l$)

$V_o$ velocity in the undisturbed stream

a speed of sound

M Mach number ($V_o/a$)

The drag, cross-wind force, and center-of-pressure coefficients for the .50-caliber machine gun without barrel jacket are shown plotted against Mach number in figure 2 for several angles $\alpha$. As was the case in reference 1, the force coefficients are based on the axial cross-section area of the gun in the air stream. The area of the plain barrel is about 38 percent less than the corresponding area of the standard gun.

A comparison of the drag coefficient variation with Mach number (fig. 2) for equal positive and negative values of angle shows quite unexpected differences. Except for an angle of 60°, the curves for angles with the gun barrel pointing aft show the sharp rise in drag coefficient

associated with Mach number effects for speeds beyond the critical speed. For the forward (positive) angles, however, this rise in drag coefficient is much more gradual or entirely lacking. An explanation for this difference is not possible from the data obtained. It may be suggested, however, that, in addition to the complication of three-dimensional flow, the taper in the gun barrel and the air leakage through the small clearance gap between the gun barrel and the tunnel wall may have produced - or aided in producing - sufficient change in the type of air flow, and hence separation phenomena, about the gun to account for the difference in drag behavior for positive and negative angles. One effect of taper in the barrel is that sections of the barrel exposed to the air flow are more streamlined when the gun points aft than when it points forward. Also, when the gun points forward there is a cross-flow tendency toward the breech end and, when it points aft, toward the muzzle end.

From the data of figure 2 it is evident that critical Reynolds number effects, characterized by an appreciable decrease in drag coefficient with increase in Reynolds number as exemplified by the drag data for the unslotted replica of reference 1, did not develop for the plain barrel because of the onset of compressibility phenomena at those speeds at which the drag decrease could be expected. For a given size of cylinder, critical Reynolds number effects can be made to

occur at lower velocities by increasing the initial turbulence of the stream or by introducing roughness on the surface of the cylinder (reference 2). Recourse was made to the second of these methods in an effort to decrease the barrel drag. Roughness was produced by shellacking the barrel surface and then dusting no. 60 carborundum grains uniformly on the wet shellac. When dry, the shellac firmly bonded the grains to the barrel surface. As figure 2 illustrates, the disturbance to the air flow introduced by the carborundum particles was not sufficiently great to decrease the critical Reynolds number. A larger size of carborundum grain may have shown more favorable results. However, the test does bring out the fact that the drag of the barrel is not adversely affected by roughness, being actually less at high Mach numbers. This means that, as far as aerodynamic considerations are involved, a barrel finish produced by a rough machining operation is no worse - but probably somewhat better - than one produced by a fine machining operation.

The drag coefficient of the plain barrel is about 29 percent greater than that of the standard gun, but, since the exposed area in the air stream is reduced by 38 percent when the barrel jacket is eliminated, there is an appreciable drop in pounds of drag for the gun without the jacket. The proper comparison of the drag of the machine gun with and without barrel jacket is brought out in figure 3 in which actual drag

in pounds is plotted against speed for sea-level conditions. Figures 3 and 4 are based on the drag coefficient data of figure 2 and reference 1 for $\alpha = 0^{\circ}$. In converting to sea-level conditions, the data were computed for the correct Mach number. The Reynolds number for the flight sea-level example differs slightly from the values obtained in the wind-tunnel test at the same Mach number, but the effect of this difference is inappreciable on the value of the drag-force reduction due to the elimination of the jacket. By eliminating the barrel jacket it is seen that the drag of the gun when vertical to the air flow is reduced by 23 percent. At 350 miles per hour the drop in drag is from 83 pounds to 64 pounds. Also included in figure 3 is the drag of the barrel when roughened with carborundum grains. Above 400 miles per hour there is a decrease in drag due to roughness on the surface. This improvement may be due to less adverse separation characteristics when roughness is introduced. Figure 4 shows the horsepower absorbed in air drag by a machine gun with and without barrel jacket. Eliminating the barrel jacket decreases the horsepower absorbed in drag from 78 to 60 horsepower at 350 miles per hour.

The center-of-pressure data shown in figure 2 are somewhat less accurate because of smaller forces than the corresponding data for the standard gun of reference 1. The $C_p$ curve for $60^{\circ}$ aft was not faired because of the scatter of the test points.

## CONCLUSIONS

By eliminating the barrel jacket of a .50-caliber aircraft gun, the drag was reduced 23 percent; or, at 350 miles per hour and sea-level conditions, the drag decreased from 83 to 64 pounds.

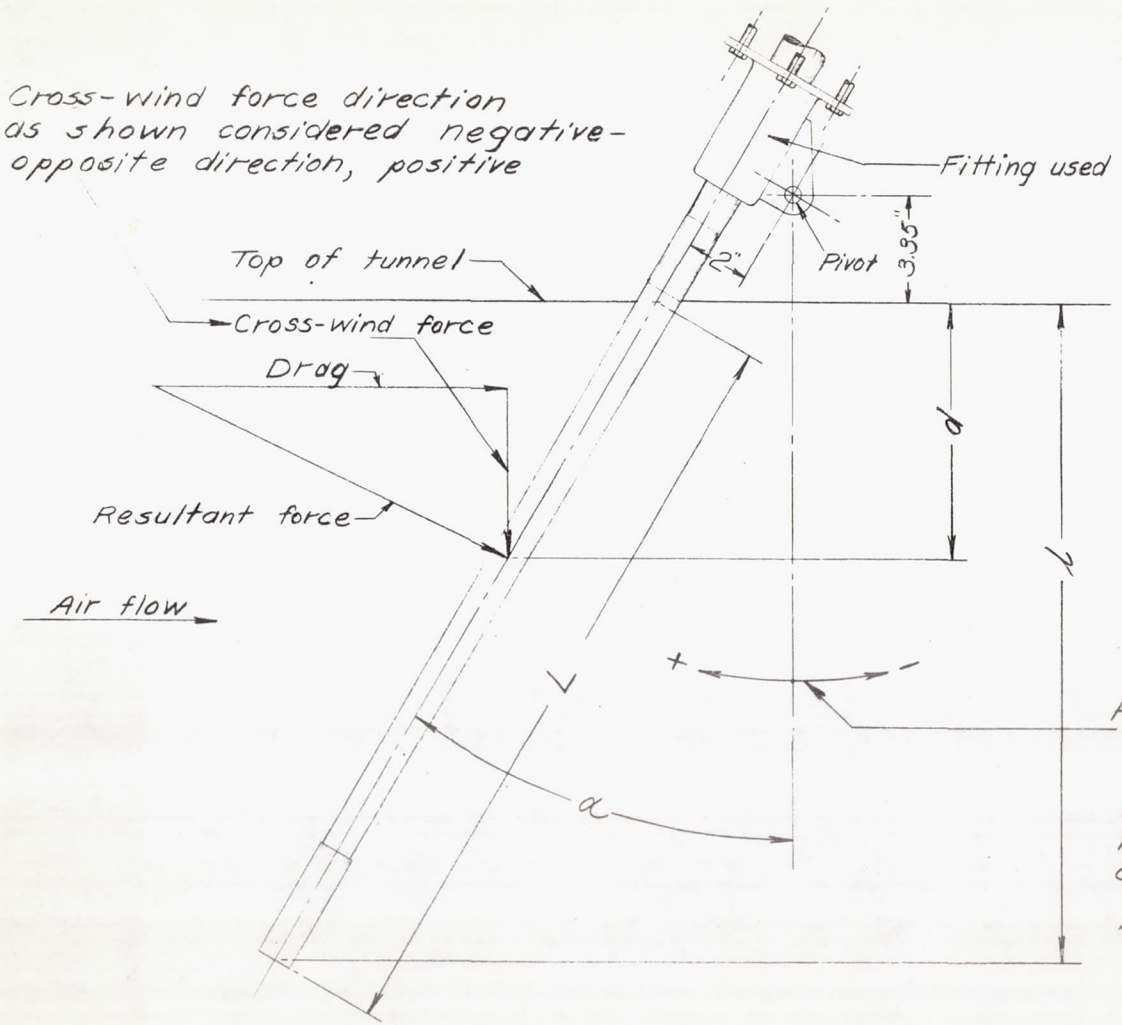
A rough surface finish on the gun barrel had no adverse effects on the drag.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 26, 1943.

## REFERENCES

1. Luoma, Arvo A.: Drag Measurements of a Protruding 0.50-Caliber Machine Gun. NACA A.C.R., July 1941.

2. Fage, A., and Warsap, J. H.: The Effects of Turbulence and Surface Roughness on the Drag of a Circular Cylinder. R. & M. No. 1283, British A.R.C., 1930.




| α (deg) | A (sq ft) | L (in.) | l (in.) | $D_a$ (in.) |
|---|---|---|---|---|
| 0 | 0.203 | 25.5 | 25.5 | 1.146 |
| ±15 | .198 | 24.9 | 24.1 | 1.144 |
| ±30 | .188 | 23.8 | 20.6 | 1.138 |
| ±45 | .174 | 22.1 | 15.6 | 1.130 |
| ±60 | .144 | 18.6 | 9.3 | 1.114 |

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Figure 1.- Dimensions of 0.50-caliber machine gun barrel.

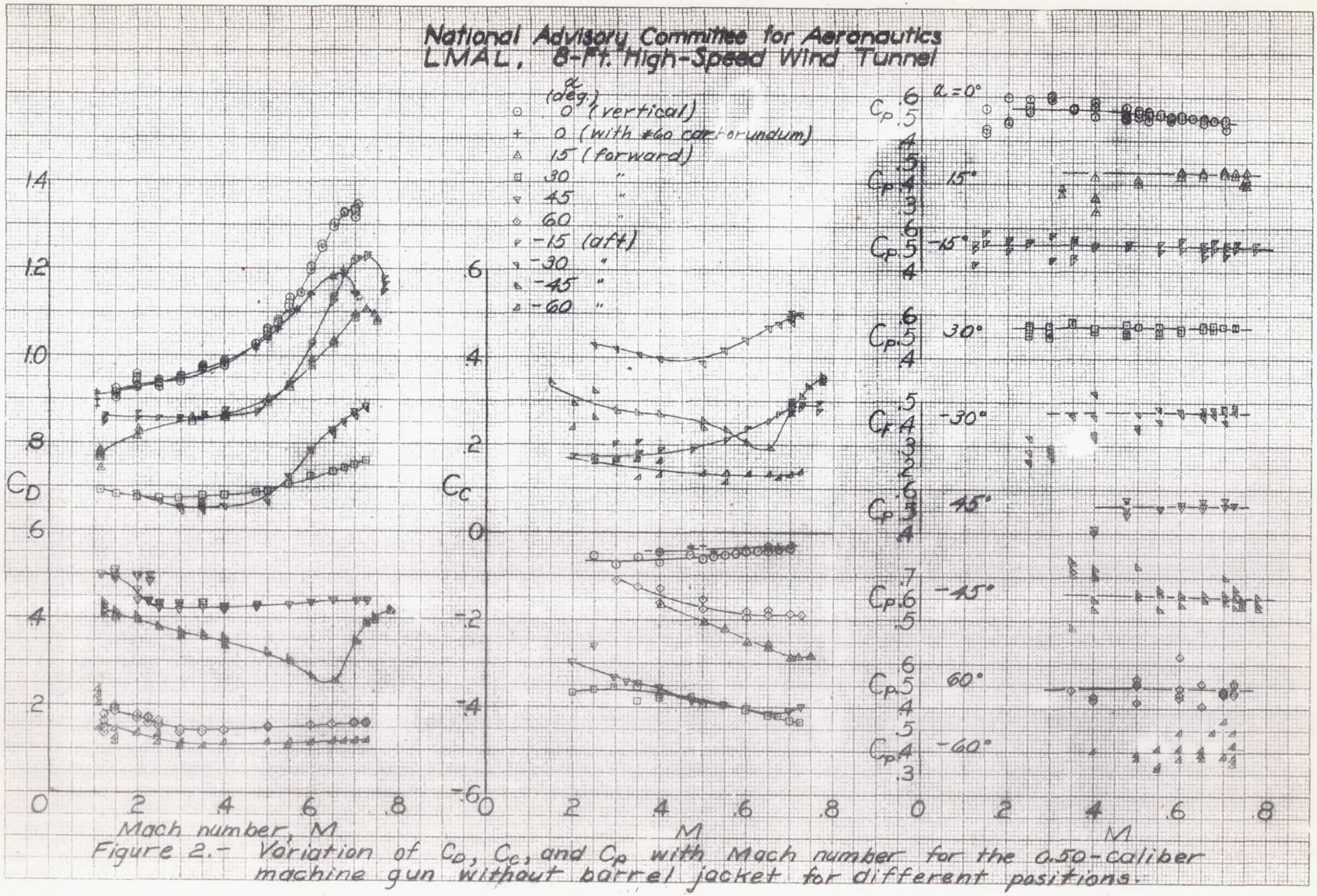


Figure 2.- Variation of $C_D$, $C_C$, and $C_p$ with Mach number for the 0.50-caliber machine gun without barrel jacket for different positions.

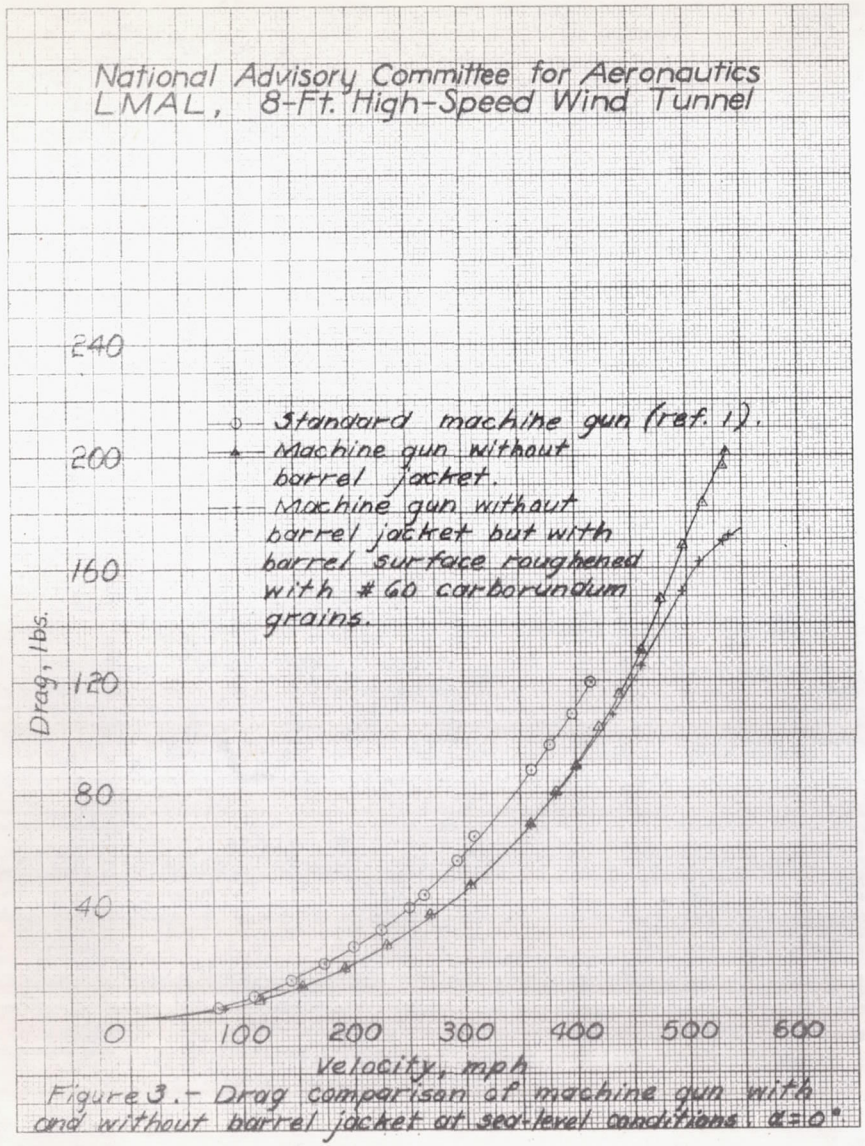


Figure 3.- Drag comparison of machine gun with and without barrel jacket at sea-level conditions. $\alpha = 0°$.

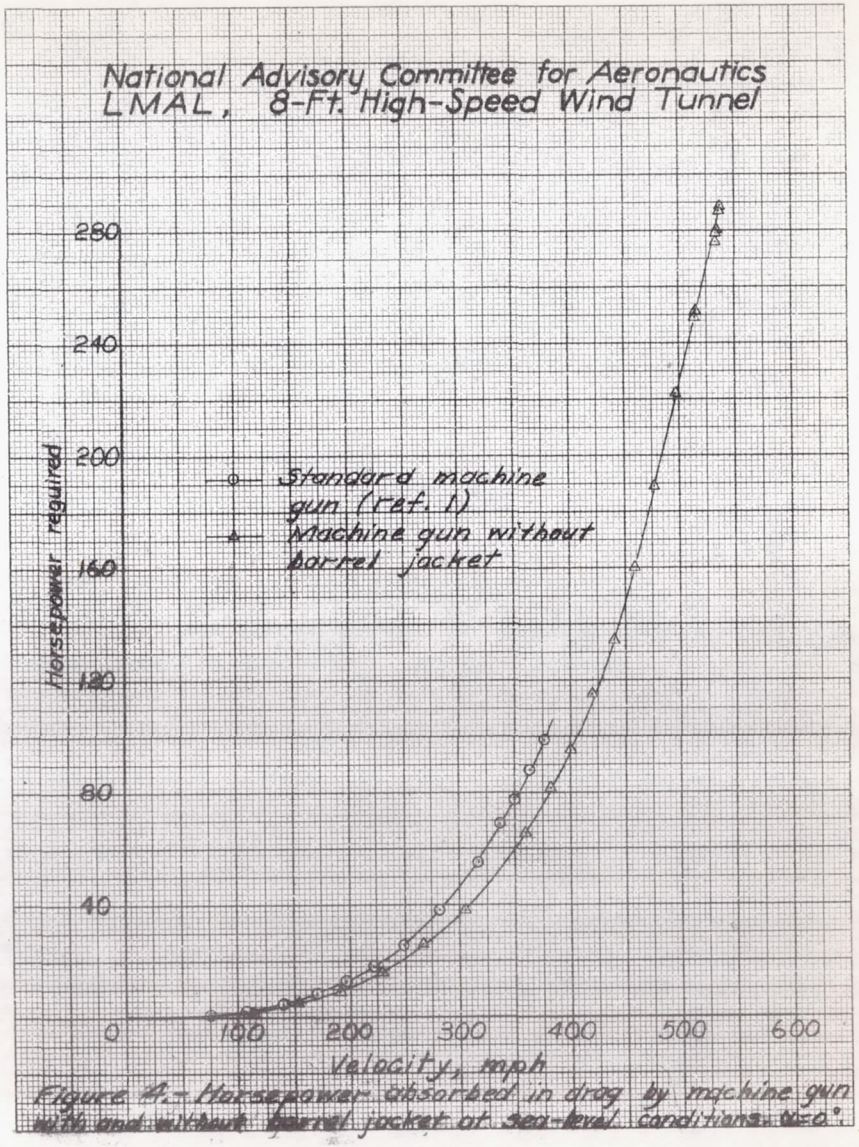


Figure 4.- Horsepower absorbed in drag by machine gun with and without barrel jacket at sea-level conditions. $\alpha = 0°$.